

East Maui Watershed

Monitoring Review & Recommendations



Final Report
June 2006



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Executive Summary

After 10 years of implementing the original watershed management plan, the East Maui Watershed Partnership (EMWP) recommended an update of the original plan as well as a review and revision of its 1996 monitoring plan. In response to these recommendations, a small core team formed to review current and past monitoring and to make recommendations to the EMWP monitoring subcommittee for the next generation of monitoring. The core team consisted of natural resource managers from EMWP, the State Department of Land & Natural Resources (DLNR), and The Nature Conservancy of Hawai'i (TNCH). The core team's goals were to:

- Briefly review current and past monitoring methods and protocols;
- Clarify management goals and objectives that influenced monitoring choices; and
- Make recommendations to the EMWP's monitoring subcommittee about the next generation of monitoring on East Maui.

The core team focused on developing a *realistic* and *effective* monitoring scheme using these guidelines: less not more, data used by managers, cost effective, and minimal impact to native ecosystems. Initial recommendations were revised by the EMWP monitoring subcommittee to produce this final report. The team did not make explicit recommendations for areas within Haleakalā National Park (HALE). HALE has many ongoing monitoring activities, many of which are related to research questions. HALE staff contributed to, and many of their monitoring methods laid the groundwork for the recommendations outlined in this report.

Monitoring recommendations focused on four areas: *ungulates*, *weeds*, *vegetation*, and *water resources*. The new recommendations were more closely tied to answering questions that trigger management actions than the 1996 plan. Monitoring objectives were developed or clarified for each of these topic areas and current practices and methods were reviewed. New recommendations were developed based on what was working and what was not.

Ungulate monitoring recommendations largely supported current methods but changed the location and number of transects. One major revision was to stop monitoring ungulate activity along portions of the U.S. Fish & Wildlife Service (USFWS) bird survey transects each year. Instead, annual scouting should be conducted in management units with very low or no current ungulate activity. Monitoring along systematically placed transects should be conducted in management units that have moderate to high levels of activity. Another key recommendation was to survey the biological resources and threats in areas below the current high-elevation fence to support the creation of new management units and goals. In addition, existing ungulate activity data from 8 transects initially installed in the public hunting area below the fence should be summarized for and reviewed by the EMWP monitoring subcommittee in the near future. Transect location and number, sampling frequency, and usefulness of these data/transects should be updated, revised, and brought into alignment with the recommendations in this report.

Weed monitoring recommendations generally supported current activities. Weed monitoring in the East Maui watershed has not been highly coordinated, nor have methods been much aligned among partners. In most cases, this *ad hoc* approach has worked sufficiently because of differences in goals and objectives among management units. Thus, the core team had difficulty developing new recommendations for weed monitoring. Several coordinated efforts were explored in depth including comprehensive mapping of high priority habitat modifiers and

systematic weed sampling. Uncertainties about the methods themselves, the time and resources needed, and the usefulness of the resulting information were significant. No new activities were proposed.

Vegetation monitoring recommendations centered on evaluating changes in the extent and quality of native vegetation. For Hawai'i managers, the extent and quality of native vegetation (more native plants = healthier ecosystem, thus, watershed) is a robust indicator of ecosystem health. Measuring changes in other ecosystem components and species will obviously be important but is better accomplished with specific studies set up to address specific questions. Recommendations included comprehensive vegetation mapping every 5-10 years and initiation of a low-altitude pilot helicopter survey below the fence.

Water resources monitoring recommendations were focused on continuing and supporting current agencies and partners who have a mandate to collect data. Effort should be made to try and increase the number of active U.S. Geological Survey (USGS) surface water gauging stations (currently 3 exist).

In general, the recommendations in this report supported the continuation of many current monitoring activities. However, several new efforts were recommended that require additional resources than currently available. These included:

- (1) A baseline inventory for areas below the fence that is used to propose new active management units and objectives;
- (2) Comprehensive vegetation mapping; and
- (3) A pilot helicopter survey of vegetation and threats.

Of these, money is available to initiate a pilot helicopter survey. However, if results are favorable and expansion of the surveys is recommended, new funding resources will be needed.

In addition, 6 priority research needs were identified:

- Perform a comprehensive analysis of past ungulate data;
- Determine optimum/minimum transect coverage for Transect AMUs;
- Update pig population estimates, demography, movement, and behavior, particularly in unfenced management units;
- Develop a cost-effective method for measuring changes in weed distributions over time and across the watershed;
- Develop better estimates of rainfall at mid-elevations; and
- Investigate the link between management actions and water quantity and quality.

The next step is for the various partners of the East Maui watershed to determine if and how these new monitoring efforts and priority research needs can be accomplished.

Finally, it was clear from the monitoring review that a revision of the EMWP management plan is necessary and timely. The core team suggested that the updated management plan address the following issues: (1) defining explicit ungulate activity goals and timeframes for current AMUs, (2) determining explicit weed management goals for all management units, and (3) delineating new AMUs in currently unmanaged areas that capture remaining native habitat.

Introduction

Conservation and land management actions have been implemented in the East Maui watershed for several decades. The majority of these actions focus on reducing the most critical and urgent threats to native ecosystems and species, which in turn, ensure protection of the East Maui mountains freshwater supply. Actions have been carried out by individual land owners such as the National Park Service (NPS), The Nature Conservancy of Hawai‘i (TNCH), and the State Department of Land & Natural Resources Division of Forestry and Wildlife (DLNR-DOFAW). In 1991, the East Maui Watershed Partnership (EMWP) formed and united all major landowners on East Maui to work collectively to protect the East Maui watershed. A watershed management plan was written soon after (East Maui Irrigation 1993).

A comprehensive monitoring plan was also developed following the formation of the EMWP (TNCH 1996a). Some components of the plan were implemented, others revised, and others determined too resource-intensive to pursue. As a result, a rather *ad hoc* monitoring scheme developed over the years that varies among landowning partners, although some monitoring objectives and methods, such as for ungulates, are quite similar.

In April 2004, the EMWP held an all-partner retreat to discuss the progress and challenges of the partnership in achieving its primary goals. One of the consensus recommendations was to review and revise the 10-year old management and monitoring plans. Enough work had been done and much evolution taken place since the original plans were developed. It was time for a fresh look at monitoring objectives and methods, and to make recommendations to continue what was working and to change what was not working.

In response to the retreat recommendations, a small core team¹ formed to review current and past monitoring and to make recommendations to the EMWP monitoring subcommittee for the next generation of monitoring on East Maui. The core team’s goals were to:

- Briefly review current and past monitoring methods and protocols;
- Clarify management goals and objectives that influenced monitoring choices; and
- Make recommendations to the EMWP monitoring subcommittee about the next generation of monitoring on East Maui.

It should be noted that the core team focused on developing a *realistic* and *effective* monitoring scheme with an emphasis on several key guidelines: less not more, data used by managers, cost effective, and minimal impact to native ecosystems. An initial set of ideas were presented to the EMWP monitoring subcommittee and other partners on April 12, 2005. Excellent feedback was provided by the 18 workshop participants (Appendix 1). This final report incorporates that input. The team did not make explicit monitoring recommendations for areas within Haleakalā National Park (HALE). HALE has many ongoing monitoring activities, many of which are related to research questions. HALE staff contributed to, and many of their monitoring methods laid the groundwork for the recommendations made in this report.

¹ Jordan Jokiel, Natural Resource Manager, EMWP; Bryon Stevens, Natural Area Reserve Specialist, DOFAW; Melissa Chimera, Natural Resource Manager, TNCH.

East Maui Watershed

The lands under the jurisdiction of the EMWP span over 40,000 hectares [98,840 acres] of the Makawao and Hāna Districts of Maui (Figure 1). Elevations range from sea level along the windward coast to over 3,000 meters [9,800 ft] in Haleakalā National Park. Rainfall varies from 100 cm [39 inches] a year to over 760 cm [299 inches] a year in the montane wet rainforests. At its western end, the watershed includes the mauka lands of Haleakalā Ranch, the state-owned Waihou and Makawao Forest Reserves, and the forests of East Maui Irrigation (EMI). Haleakalā Ranch lands under conservation easement to TNCH form the Waikamoi Preserve. The central region mauka of the Hāna highway is dominated by state-owned Koʻolau Forest Reserve and Hanawī Natural Area Reserve (NAR). Hāna Ranch lands adjoin Hāna Forest Reserve along the eastern edge of the watershed. Haleakalā National Park includes the entire summit region and Kīpahulu Valley to the east.

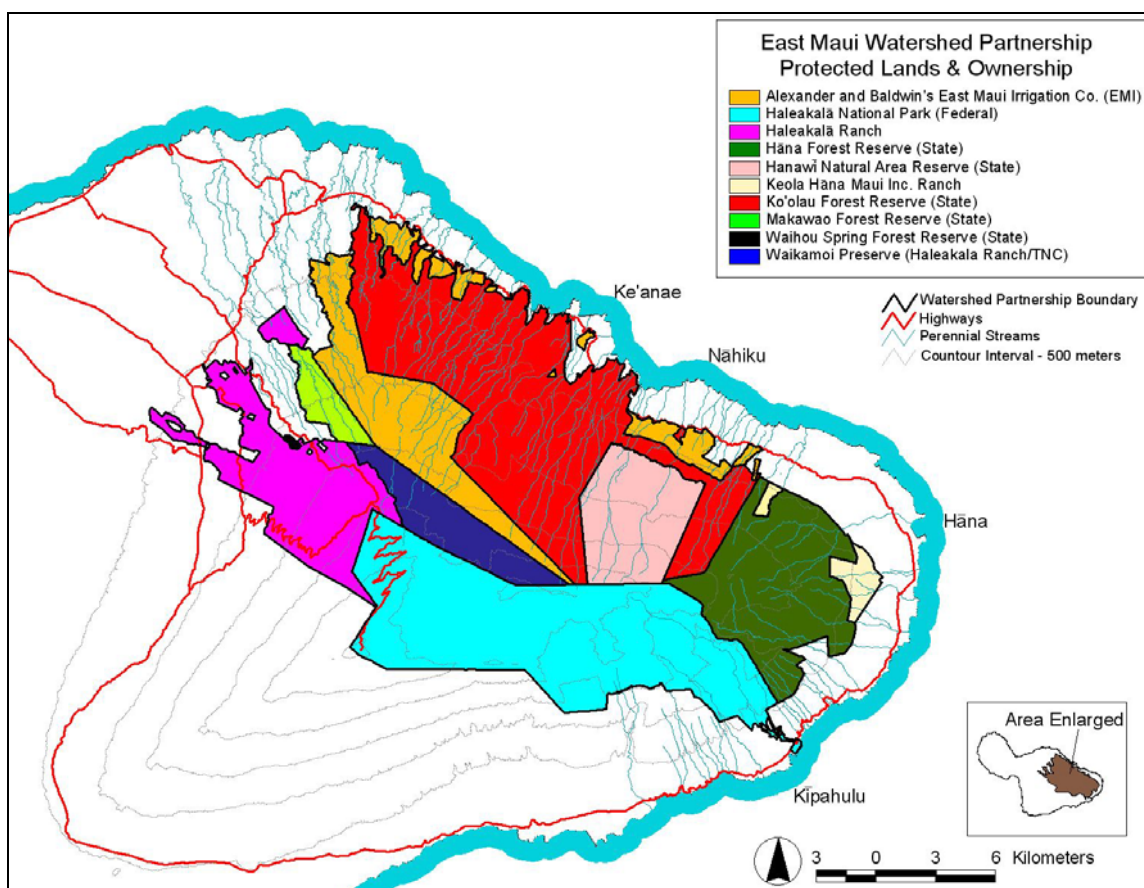


Figure 1. Landowners in the East Maui watershed.

The East Maui watershed contains some of the most important natural resources in the state of Hawai'i. The watershed is the largest single source of surface water, with an average harvested flow of 60 billion gallons [227 billion liters] per year. Forty-eight streams originate from the watershed; 35 of them are perennial and 13 are intermittent. Maui County estimates that total water use will increase from approximately 170 million gallons per day (MGD) [644 million liters per day] in 1987 to 186 MGD [704 million liters per day] by the year 2010. The total potential water from the East Maui watershed is estimated at 489 MGD [1.8 billion liters per day], or 179 billion gallons [678 billion liters] per year!

Data analyses by The Nature Conservancy show that, ecologically, the East Maui watershed contains vast areas of native-dominated rainforest, unique natural communities, and scores of endemic species. Over 34,000 hectares [84,000 acres] of native-dominated ecosystems occur on EMWP lands. Most of this native-dominated area is rainforest (38% is Lowland Wet Forest and 33% is Montane Wet Forest), but also includes mesic forests, cliffs, subalpine, and alpine ecosystems (Hawai'i Natural Heritage Program 2003a). The watershed contains nearly one-third of Hawai'i's remaining endemic species of flowering plants (i.e., 263 species of which 35 are endangered; Price 2000) and nearly half of all endemic, viable bird species found in the state (personal communication; Eric VanderWerf, Jay Nelson, and Catherine Swift, USFWS). Eight types of rare natural communities occur in the watershed, including a silversword community, a bog community, and numerous perennial streams (Hawai'i Natural Heritage Program 2003b).

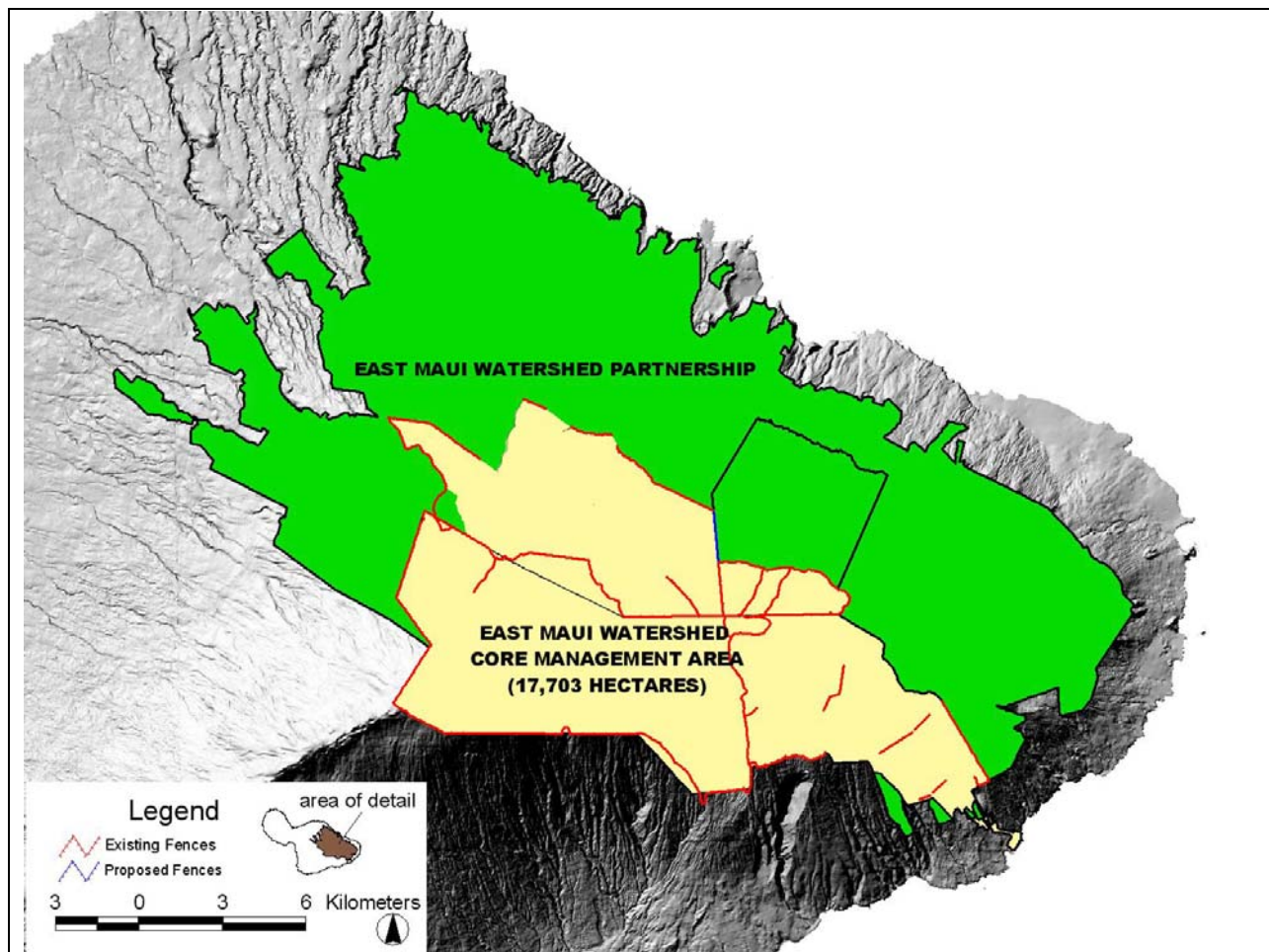


Figure 2. Core management area of the East Maui Watershed Partnership as of June 2006.

During the first decade plus of the partnership, a core management area was defined, an environmental assessment completed (TNCH 1996b), 11 km [6.8 miles] of fence constructed, and high-priority management actions implemented (Figure 2). The core management area represents the most intact portion of native resources as well as those areas that have been the highest priority for management.

Summary of Monitoring Recommendations in 1996 Plan

The original monitoring plan compiled in 1996 developed a set of recommendations for monitoring across the East Maui watershed (TNCH 1996a). The major recommendations from that report and the extent to which they were implemented are briefly described below.

1. ***U.S. Fish & Wildlife Service (USFWS) bird survey transects 3-9 and 11.*** After collection of baseline levels of ungulate activity, weeds, and vegetation, these transects were to be monitored every year for weeds and ungulate activity and every ten years for vegetation. The 1996 recommended protocol for vegetation was a comprehensive plot-based monitoring program based on Dunn (1992) (i.e., the “Dunn protocol”). TNCH monitored transects 3-6 for ungulate activity and weeds every year since 1996 and has analyzed the data. Transects 7-9 in Hanawā NAR were monitored for ungulate activity and weeds in 1996 and 1998. It is unclear whether these data were analyzed. No monitoring ever occurred on transect 11.
2. ***Eight transects in the accessible public hunting area below EMWP fences.*** DLNR conducted ungulate activity monitoring on an annual basis, however the data were not analyzed and much is now missing. In 2002/2003 the original eight transects in the lower reaches of the watershed were discontinued and eight new transects were established. Ungulate activity data were collected for fall 2002, spring 2003, and spring 2004. In 2006, DLNR indicated that one of the eight transects was no longer accessible and no plans are in place to replace this inaccessible monitoring transect. Therefore, seven monitoring transects are now in the lower reaches of the watershed.
3. ***East Maui Watershed transect 103*** (20 plots near the western segment of the Honomanū Makai fence, above and below the fence). This transect was never established.
4. ***Remote weather station*** at 1200 m [3,900 ft] elevation on transect 6 or 7. This station was never established.
5. ***Miconia calvenscens mapping*** on a yearly basis. The Maui Invasive Species Committee (MISC) and NPS have been mapping *Miconia calvenscens* on an ongoing basis.
6. ***Other ad hoc weed mapping and monitoring.*** Other specific weeds mapped according to management objectives and time and resources available.
7. ***Continue to collect stream flow, water quality, and rainfall data*** as appropriate agencies and partners are able.
8. ***Haleakalā National Park.*** Areas within HALE were not considered and included in the 1996 monitoring plan.

Additional details of these and other past monitoring efforts on East Maui are outlined in Appendix 2.

Summary of New Monitoring Recommendations

In developing new recommendations, the core team tried to link monitoring to management actions more closely and to considerably scale back to data that could be reasonably collected and analyzed. Monitoring the full length of the USFWS transects (transects 3-9 and 11) for ungulate activity and weeds on an annual basis (1996 recommendation) for example, was unachievable, and land managers did not have the resources to monitor where management was not underway.

To be successful, monitoring should have clearly defined goals as the first step. Is the goal to gather baseline information on a species or ecosystem? Is the goal to determine changes in specific parameters over time? Are abundance estimates needed or is presence-absence information adequate? These and other questions sound self-evident, but too often, time and effort have been wasted for lack of clearly defined objectives.

Objectives of the proposed monitoring recommendations for East Maui are summarized below. The new recommendations are more closely tied to answering questions that will trigger management actions than the 1996 plan. Specific monitoring methods are summarized in Table 1 and outlined in detail in the following chapters and appendices. A noteworthy difference between these new recommendations and those from 1996 is that recommendations differ depending on the degree to which an area is managed.

Ungulate Monitoring Objectives

- (1) To locate and respond to ungulate activity;
- (2) To evaluate the effectiveness of management actions in reducing ungulate activity;
- (3) To determine the extent to which ungulate activity objectives are met in managed units.

Weed Monitoring Objectives

- (1) To respond quickly to new high-priority invasive species;
- (2) To evaluate program effectiveness in reducing the spread of weeds.

Vegetation Monitoring Objectives

- (1) To track changes in the extent and quality of native vegetation cover over the watershed;
- (2) To answer other specific, data-intensive questions on a smaller, more appropriate spatial scale.

Water Resource Monitoring Objectives

- (1) To understand and track changes in the quantity and quality of water resources, including surface water, ground water, and rainfall.

Table 1. Summary of monitoring recommendations (AMU = Active Management Unit)

Ungulate Monitoring Recommendations
<p><i>Life History Data</i>¹ – Record the number, sex, and age of all animal catches.</p> <p><i>Scouting AMUs</i>¹ – Scout for any sign of ungulate activity along all trails, transects, fence lines, landing zones, camps, etc. at a minimum of once per year. Minimum spatial coverage = 25 meters of internal trail per hectare [33 ft of internal trail per acre] of management unit (excluding fencelines).</p> <p><i>Transect AMUs</i>² – Assess ungulate activity annually along a series of strategically placed transects by recording presence/absence of all ungulate sign in 5 x 10 m plots spaced 50 meters apart [16 x 33 ft plots spaced 164 ft apart] along each transect. Minimum spatial coverage = 5 meters of transect per hectare [7 ft of transect per acre].</p> <p><i>Unfenced Management Units</i>² – Inventory biological resources and threats. Use baseline information to propose new AMUs encompassing the highest quality native resources. Implement appropriate monitoring protocol in new units as per recommendations in this report. Analyze data from eight (now currently seven) transects in public hunting area and revise spatial coverage as necessary.</p> <p><i>Broad Scale</i>² – Determine hectares/acres managed and hectares/acres that met management objectives on a yearly basis using GIS.</p>
Weed Monitoring Recommendations
<p><i>Active Management Units</i>¹ – Monitor weeds as appropriate to the specific management objectives. Scout for weeds along trails and other infrastructure on a yearly basis.</p> <p><i>Effectiveness</i>¹ – Monitor the efficacy of weed treatments and containment as appropriate.</p>
Vegetation Monitoring Recommendations
<p><i>Comprehensive Vegetation Mapping</i>² – Map the extent and quality of native vegetation cover across the watershed every 5-10 years using all available aerial and ground-based information.</p> <p><i>Helicopter Surveys</i>² – Implement a pilot low-altitude helicopter survey (vegetation quality, weeds, ungulate activity) for areas “below the fence.” Ensure data are consistent with and feed into vegetation mapping. Develop future recommendations for helicopter surveys based on results of pilot study.</p>
Water Resource Monitoring Recommendations
<p><i>Existing Data Collection</i>¹ – Support partners and public agencies to continue collecting data on water resources (i.e., stream flow, ground water, rainfall, water quality) according to their mandates. Discuss with USGS the possibility of increasing the number of active gauging stations in the East Maui watershed. Assist water resource agencies with data collection as time and resources allow.</p>

¹ = ongoing; ² = new recommendation

Ungulates

General Context

A top priority threat to the East Maui watershed is non-native ungulates, specifically pigs, goats, deer, and cows. Of these, pigs are currently most problematic and actively managed. For goats, cows, and deer, there is generally a “no tolerance” management position in all managed units. Goats and cows were eliminated from the core area over the past two decades, and deer have not yet established in the watershed. There are perhaps two dozen deer on the western edge of the native-dominated forest (personal communication; Francis Quitazol, TNCH). Deer are much more of a potential threat along the southern boundary of Haleakalā National Park and in Kaupō Gap (personal communication; Ted Rodrigues, NPS). To date, one deer-exclusion fence has been built along the western perimeter of the core watershed area, and a second deer-exclusion fence should be completed in Kaupō Gap by the end of 2005. Aerial scouting and shooting of all ungulate species occurs as incidents are reported within the sparsely vegetated summit area of Haleakalā National Park.

Because it is nearly impossible to determine the number of animals in a management unit directly, the primary method for evaluating level of threat is by assessing activity levels or sign along trails or transects. Recommendations for measuring ungulate activity described in the following sections are meant to encompass visible sign of all ungulate species, although pig sign will comprise the vast majority.

Management Unit Nomenclature

The core team needed to define several types of management units because current ungulate activity levels varied significantly and because recommended monitoring methods depended on current activity levels. Thus, “Active Management Units” (AMUs) are those areas in the watershed that are presently managed aggressively for priority threats and where the long-term goal is to maintain or achieve zero ungulate activity (Figure 3). “Scouting” AMUs are those areas where current ungulate levels are at or near zero and where the most effective monitoring method is scouting (Figure 3). In contrast, “Transect” AMUs are those areas where current ungulate levels can range from low to high and where aggressive management actions are underway. Strategically placed transects are the most effective monitoring method in these units. As ungulate densities decrease to less than 1 pig/km² [<3 pigs/mi²] (see more below) Transect AMUs become Scouting AMUs. Areas of the watershed that are outside these AMUs generally refer to areas “below the fence” and are considered “Unfenced Management Units” for purposes of this assessment (Figure 3).

The EMWP is currently developing a draft environmental assessment for additional fence projects and has started a process to update the watershed management plan. Upon finalization and approval of that assessment and implementation of fencing actions, there will be additional active management units in the watershed.

Ungulate Monitoring Objectives

- (1) To locate and respond to ungulate activity;
- (2) To evaluate the effectiveness of management actions in reducing ungulate activity;
- (3) To determine the extent to which ungulate activity objectives are met in managed units.

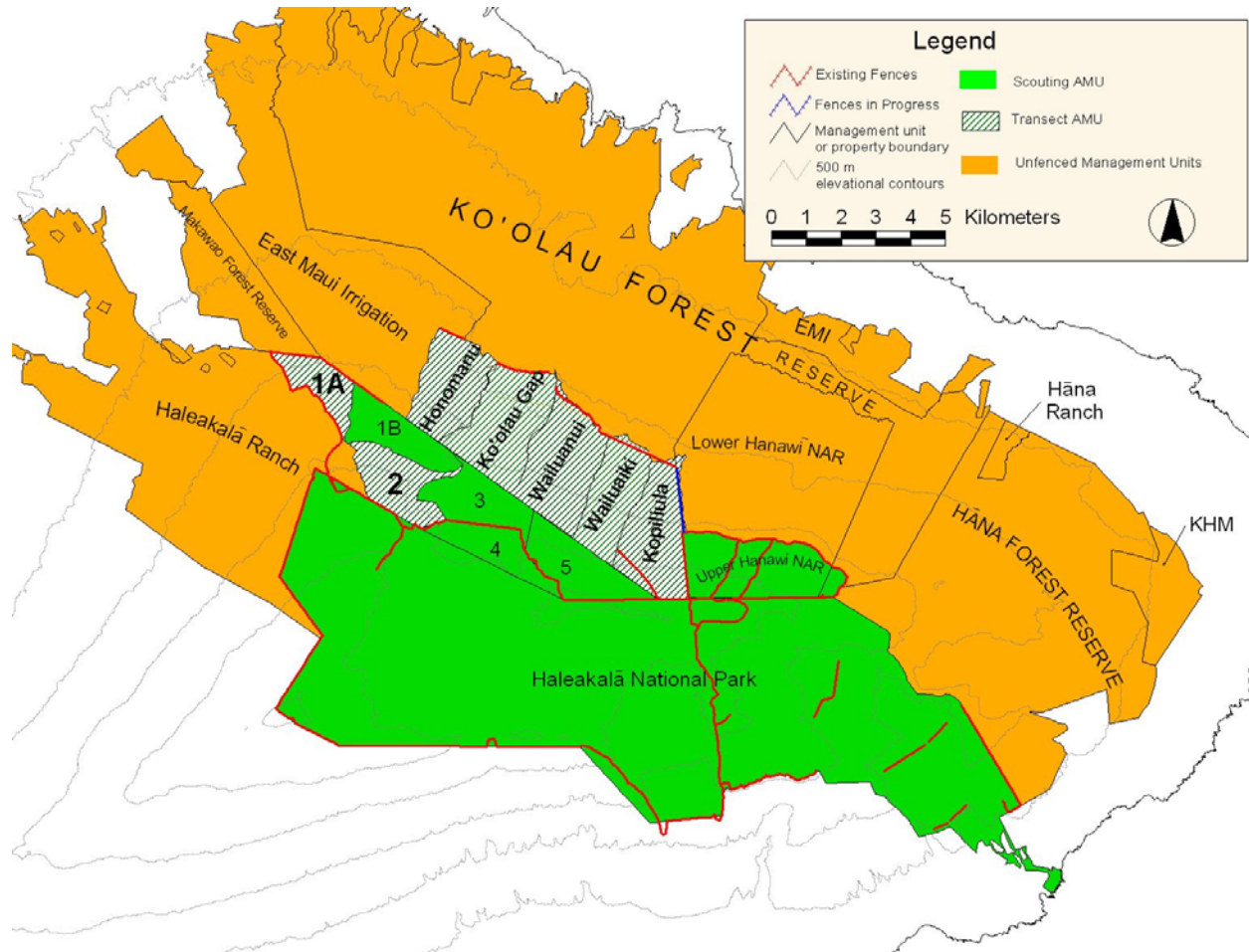


Figure 3. Active Management Units of the East Maui watershed as of June 2006. See text for definitions.

Pig Life History

In addition to activity measurements, several simple indicators of pig life history can and should be monitored in all areas with active management to inform managers of recent population trends. The primary questions this information informs are: (1) Are pigs reproducing? (2) Has the normal sex or age ratio changed, indicating a destabilized population?

Monitoring Recommendations – Pig Life History

- Collect the following information on an ongoing basis for animal catches from hunting and snaring in all managed units: *number of animals, sex, and age*.

At a minimum, age should be estimated into categories outlined on the “tooth eruption chart” (Matschke 1967).

Scouting Active Management Units

Scouting Active Management Units are areas where current ungulate activity is at or near 0%. There are approximately eight such units in the East Maui watershed (Figure 3, Appendix 3 – Table A.3.1). The questions managers ask for Scouting AMUs are: (1) Have any ungulates returned to this unit? (2) Is pig reproduction of any remaining animals increasing significantly?

Measuring activity levels along transects in units with zero or very low levels is largely uninformative to resource managers. When pig densities are extremely low (less than 1 pig/km²; less than 3 pigs/mi²) activity sign will not necessarily occur along transects (Anderson and Stone 1993, 1994). Scouting everywhere possible for any ungulate sign is the most effective way to monitor the ungulate threat at such low levels. Scouting can be defined as quickly and thoroughly searching the ground and low understory area for any animal sign as a manager is walking along a trail or through an area. The presence of *any* activity should trigger an immediate management response.

Monitoring Recommendations – Scouting AMUs

- For Scouting AMUs, monitoring should consist of scouting along existing trails, transects, fence lines, landing zones, camps, and known hotspots for any ungulate sign since the last scout. Frequency of scouting should be a minimum of once per year.
- Minimum spatial coverage = at least 25 meters of internal trails per hectare [33 ft per acre] of management unit (excluding perimeter fencelines).

The minimum spatial coverage of 25 meters of internal trails per hectare [33 ft of internal trails per acre] of management unit was derived from an assessment of what was considered “good coverage” by managers in upper Hanawā NAR.

Transect Active Management Units

Transect AMUs consist of areas where current activity levels are greater than 0% and where aggressive management actions (e.g., fencing and snaring) are underway (Figure 3, Appendix 3 – Table A.3.2). The long-term goal in these units is to reduce ungulate levels to 0%, however, it may take several decades to achieve this goal depending on available resources.

Measuring ungulate activity in Transect AMUs needs to be systematic (i.e., within plots along transects) to better discern actual changes over time. The main question asked by managers for these AMUs is: (1) Has the average activity in the unit declined over time?

Monitoring Recommendations –Transect AMUs

- For Transect AMUs, monitoring should consist of assessing ungulate activity along a series of strategically placed transects (Appendix 3 – Table A.3.2).
- Minimum spatial coverage of transects = 5 meters per hectare [7 ft per acre]. A major exception to this may occur in AMUs with densely impenetrable native vegetation such as uluhe (see Appendix 3 – Table A.3.2).
- Activity should be assessed by recording the presence of all ages of ungulate sign (except “too old,” see Appendix 4) in plots of fixed length (i.e., 5m wide x 10m long; 16 ft wide x 33 ft long) spaced every 50 meters [164 ft]. Frequency of ungulate activity should be calculated for each transect as the percentage of surveyed plots with sign. Ungulate activity for a management unit should be determined as the average frequency across all transects in that unit.
- A second measure of activity – percentage of ground disturbance – can also be collected in each plot along transects. Ungulate disturbance can be calculated for each transect as the average percentage of disturbance in surveyed plots. Ungulate disturbance for a management unit is the average percentage disturbance from all transects in that unit. Percentage disturbance should be recorded in absolute numeric values, not categories (e.g., Braun-Blanquet cover categories). Percentage disturbance should not be a required metric, and should be collected only when this information is useful to managers.
- Activity monitoring should be conducted annually and generally at the same time of year (i.e., within the same quarter).

The recommended minimum spatial coverage of 5 meters of transect per hectare [7 ft of transect per acre] of management unit was derived from an assessment of current transect coverage in East Maui AMUs (Appendix 3 – Table A.3.2). Five meters per hectare is an achievable minimum for most units, and this spatial coverage was also recommended by Dunn (1992). Currently, four Transect AMUs do not achieve this minimum coverage and thus, additional transects are recommended (Appendix 3 – Table A.3.2).

In Hawai‘i, there has been much debate by natural resource managers on the definitions and use of different ages of ungulate sign. Common categories include fresh, intermediate, old, and/or hunter fresh, old, and too old. “Too old” is defined as too old to be of use to managers in assessing levels of activity in the past year. Appendix 4 provides more detail on the recommended definitions for age of ungulate sign.

Finally, in addition to collecting information on presence/absence of ungulate activity, measuring changes in percentage ground disturbance may inform managers of ecosystem recovery over time. Managers can use this information to identify sections of a management unit or even sections of a transect where pigs are most active, thereby guiding live trap placement. Changes in percent disturbance often times occur more quickly than changes in presence/absence of ungulate activity.

Unfenced Management Units

Areas currently “below the fence” are considered unfenced management units (Figure 3) and public hunting is the only animal control activity. Following approval of the original management plan for the East Maui watershed, EMI and DOFAW entered into a right-of-entry agreement enabling public hunters to utilize EMI roads. This significantly increased public access in the Ko‘olau Forest Reserve to assist in the control of pig populations. It is not the intent of DOFAW to run a sustained yield hunting program, nor to remove all ungulates in unfenced management units. Allowing hunters access to harvest these ungulates satisfies DOFAW’s mandates to provide for hunting opportunities and pending data analysis, protect water resources. Ungulate activity is measured across some of this portion of the watershed. DOFAW originally monitored eight transects (Figure 4) twice a year for ungulate activity. One transect is no longer accessible and there are no plans to install an additional transect. Therefore, seven transects are now monitored twice a year for ungulate activity. No analysis or reporting has been done (personal communication; Shane DeMattos, DOFAW).

In addition to the seven transects that are monitored by DOFAW staff, DOFAW monitors the level of effort expended by hunters to remove animals from the unfenced management units in the Ko‘olau and Makawao Forest Reserves. Data on the number of hunters and dogs, hours of hunting and boars and sows taken are recorded and tabulated every six months. Data over the past two years have shown a stable pig harvest, but the amount of effort to harvest an animal has increased (personal communication, Shane DeMattos, DOFAW).

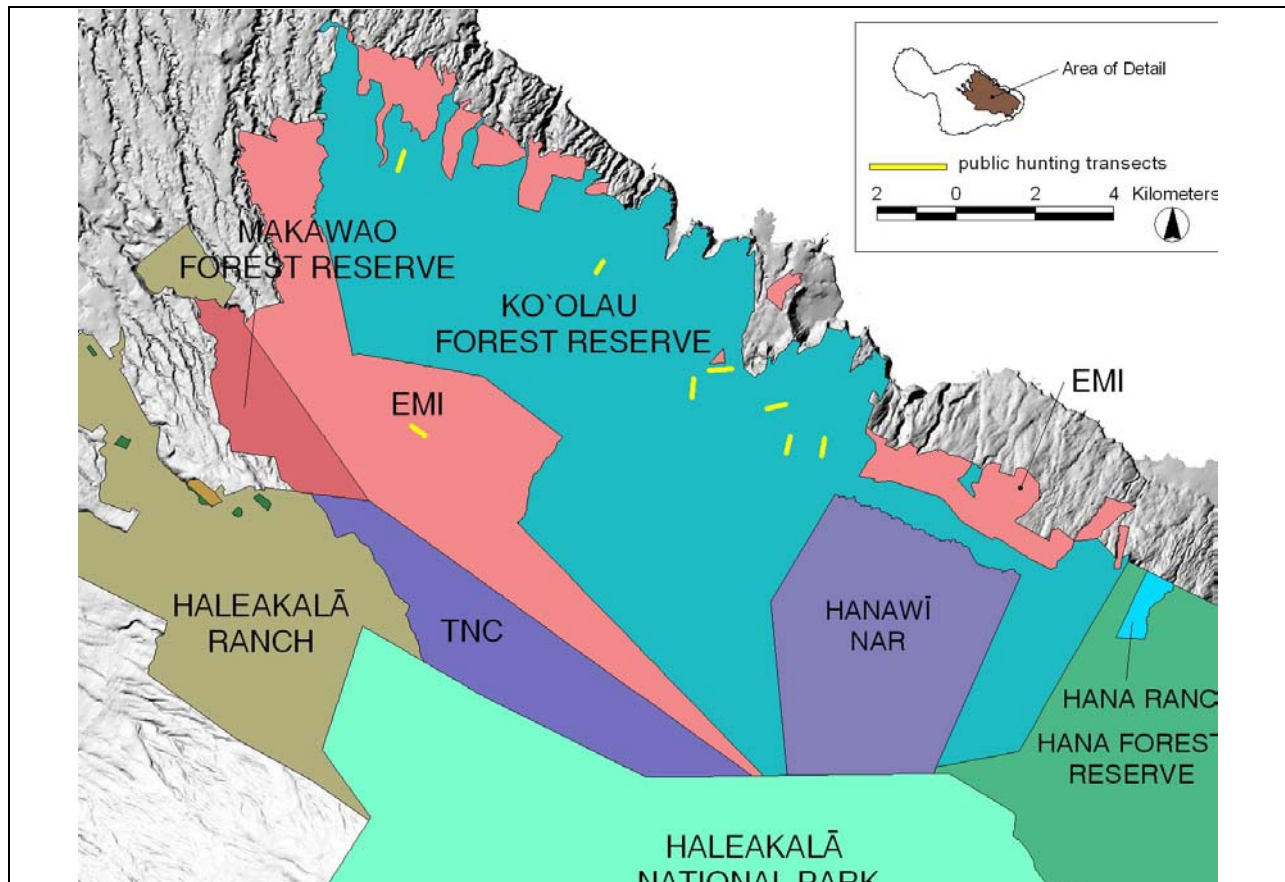


Figure 4. Ungulate activity transects in public hunting area monitored by DOFAW.

As previously stated, a second environmental assessment is under development that will propose additional fencing and management actions in currently unfenced management units. As new fenced management units are added, ungulate activity levels will be assessed and management objectives developed.

Monitoring Recommendations – Unfenced Management Units

- For unfenced management units, conduct a baseline inventory of biological resources and threats.
- Use baseline information to define new AMUs encompassing the highest quality native resources. Implement appropriate monitoring protocol in new units as per recommendations in this report.
- Summarize existing ungulate activity data along transects in public hunting area and present to EMWP monitoring subcommittee. Based on review of these data, revise and update sampling protocol.

Baseline inventory efforts should focus primarily on remaining native-dominated ecosystems rather than degraded areas dominated by alien species. A rapid assessment of ungulate activity, priority weeds, and native vegetation should be conducted. The baseline information should then be used to define new Transect AMUs encompassing the highest quality native resources. Ungulate monitoring for new Transect AMUs should follow recommendations outlined above (i.e., strategically placed transects read on an annual basis).

In addition, ungulate activity data along the transects in the public hunting area should be summarized for and reviewed by the EMWP monitoring subcommittee. The results from monitoring in the public hunting area are not widely known. Transect location and number, sampling frequency, and usefulness of these data/transects should be reviewed by the EMWP monitoring subcommittee and protocol should be updated, revised, and brought into alignment with the recommendations in this report (e.g., reduce frequency of sampling, increase or adjust spatial coverage of transects).

Broad Scale

Several simple GIS-based statistics should be generated annually to inform progress on management across the watershed. Questions managers ask in the broad scale assessment include: (1) Have additional ungulate management areas been added this year? (2) To what extent are ungulate activity objectives met for Scouting and Transect AMUs on an annual basis?

Monitoring Recommendations – Broad Scale

- Hectares [acres] managed and hectares [acres] with management objectives met should be determined on a yearly basis using GIS maps and techniques. Hectares [acres] with management objectives met should be estimated from monitoring data described above.

Weeds

General Context

Monitoring invasive weeds in the East Maui watershed occurs at several scales and levels of intensity, depending on program resources, accessibility, and current management goals. Many of the East Maui watershed partners conduct invasive weed monitoring particularly for already established high-priority species (see Appendix 5 for details on high-priority species). In addition, MISC tracks incipient, newly established species and focuses a significant portion of their time and resources on *Miconia calvescens*.

In general, weed monitoring has not been highly coordinated, nor have methods been much aligned among partners. In most cases, this *ad hoc* approach has worked sufficiently because of differences in management goals and objectives.

The core team had difficulty developing new recommendations for weed monitoring across the East Maui watershed. Several coordinated monitoring efforts were explored in depth including comprehensive mapping of high priority habitat modifiers and systematic weed sampling across a broad area. Unfortunately, the core team could not reach consensus on either of these methods. Uncertainties about the methods themselves, the time and resources needed, and the usefulness of the resulting information were significant. Development of a systematic weed survey method is identified as a priority research need (Appendix 9).

Weed Monitoring Objectives

- (1) To respond quickly to new high-priority invasive species;
- (2) To evaluate program effectiveness in reducing the spread of weeds.

Within AMUs

It is important to continue AMU-specific weed monitoring. Because each AMU has different weed management goals and objectives, a more flexible monitoring scheme must be used. The main questions asked by managers for AMUs are: (1) Have we effectively contained or eradicated the focal weed species and locations? (2) Have we accidentally brought new weeds into the unit via our gear or equipment?

Monitoring Recommendations – Within AMUs

- Monitor weeds as appropriate to the specific management objectives for a given area.
- Continue to scout for weeds along trails and other infrastructure on a yearly basis.
- Strive for some level of coordination with adjacent AMUs and increase sharing of data and information among partners.

Although often focused within unfenced management units, this recommendation also applies to the extensive and focused weed monitoring currently done by MISC for the highest priority incipient species (e.g., *Miconia calvescens*).

Efficacy

Individual managing agencies and partners are conducting basic efficacy monitoring for weed treatments and containment activities. These monitoring activities should continue. This information would primarily inform the questions: (1) What is the best treatment method for a given weed species? (2) Are the treatment and containment methods currently used working?

Monitoring Recommendations – Efficacy

- Continue to monitor the efficacy of weed treatments and containment as appropriate within AMUs.

Vegetation

General Context

Vegetation monitoring, as practiced in natural areas in Hawai‘i, has often been an exercise in frustration. Monitoring protocols such as those outlined by Dunn (1992) have attempted to track numerous parameters, such as foliar cover, stem counts, seedling recruitment, canopy cover, vigor, phenology, etc. Many past efforts were overly ambitious, difficult to evaluate, and frequently did not inform or improve management on the ground. Some of the methods, such as estimating cover, were highly subjective causing large variations and observer bias. In the event that two data sets could be compared, the information was generally expressed in the form of “more/less” of this taxon than before. Such information may be useful for studying trends of a single species, but without complex multivariate analysis, has little value for managers who are interested in evaluating trends in ecosystem health as a whole.

For Hawai‘i managers, a robust overall indicator of ecosystem integrity is the extent and quality of native vegetation (more native plants = healthier ecosystem, thus, watershed). This basic assumption can form the foundation for a simpler, more straightforward monitoring protocol. The recommendations for vegetation monitoring on East Maui outlined below focus primarily on measuring the extent and quality of native ecosystems. Measuring changes in other ecosystem components and species will obviously be important but is better accomplished with specific studies set up to address specific questions.

Vegetation Monitoring Objectives

- (1) To track changes in the extent and quality of native vegetation cover over the watershed;
- (2) To answer specific, data-intensive questions on a smaller, more appropriate spatial scale.

Comprehensive Vegetation Mapping

Mapping the extent and quality of native vegetation cover over the watershed should be the main focus of vegetation monitoring for East Maui. Such comprehensive mapping was done in the early 1980s (Jacobi 1989) and updated in the mid 1990s (personal communication; Sam Gon, TNCH). It is again time to develop an updated vegetation map for the East Maui watershed. The primary question vegetation mapping would inform is: (1) Have the extent and quality of native vegetation declined since the previous mapping, and if so, where and by how much?

Monitoring Recommendations – Comprehensive Vegetation Mapping

- Map the extent and quality of native vegetation cover across the watershed every 5-10 years using all available information including aerial and satellite imagery and helicopter and ground surveys (see next section).
- Use simple categories for designating vegetation type and quality (Appendix 6). Develop one set of vegetation type and quality categories that will be used by all appropriate partners to ensure consistency and repeatability across different efforts.

Vegetation quality on Maui was recently assessed by DOFAW to help state managers determine appropriate management objectives. This assessment yielded a map that is very coarse and in draft form only. Although it was based largely on anecdotal information with little to no field validation of the results, the process and mapping designations can form the basis of a vegetation quality mapping protocol for East Maui partners. These DOFAW results and the new categories recommended for future mapping exercises are presented in Appendix 6.

Helicopter Surveys

Low-level helicopter flights are also recommended for monitoring vegetation quality and in developing the broad-scale maps outlined above. Aerial photos and satellite images have limitations, particularly in making distinctions between levels of degradation. The East Maui watershed is large and hard to traverse on foot, so ground-based information will also be limited.

There are several potential approaches to using low-altitude helicopter surveys to monitor vegetation quality. Surveys could consist of *ad hoc* methods that primarily take advantage of scheduled management trips to remote areas. Alternatively, surveys could be systematic and more comprehensive. For example, a grid with observation points spaced at 500 or 1,000 meters [1,600 or 3,300 ft] (e.g., approximately 400 points at 1,000 m spacing) could be established and surveyed. Each point would be visited by helicopter and simple information collected (such as vegetation quality category, extent of priority weeds, and visible ungulate activity; see Appendix 7). Such stations could be considered “permanent plots” and monitoring could occur on a 3-5 year basis. A systematic grid survey would require a fair amount of time, resources, and technical work in advance (e.g., pre-loading points into GPS). A third survey alternative would involve flying the helicopter at elevational contours and stopping to make observations at a pre-determined distance from the last point (e.g., 500 or 1,000 meters; 1,600 or 3,300 ft).

Most low-altitude helicopter surveys on East Maui have focused on finding and mapping *Miconia calvescens*. Thus, the recommendation at this time is to develop and implement a pilot helicopter survey that compares several different sampling methods. One logical geographic focus of the recommended pilot survey is unfenced management units for which inventory and mapping of vegetation, weeds, and ungulate activity was recommended. Results from the pilot survey could then be used to develop future recommendations for helicopter surveys.

Monitoring Recommendations – Helicopter Surveys

- Develop and implement a pilot helicopter survey for vegetation quality, weeds, and ungulate activity. Focus this pilot on unfenced management units and use information to help develop new AMUs within the next year.
- Ensure data are consistent with and feed into comprehensive vegetation mapping.
- Develop future monitoring recommendations for helicopter surveys based on results and lessons learned during the pilot study.

Water Resources

General Context

East Maui watershed partners, agencies, and research institutions operate, maintain, and record water resource data and information. These entities include EMI, DLNR, NPS, Department of Water Supply (DWS), the State Department of Aquatic Resources (DAR), and the USGS. Several of these entities and agencies have monitored the surface and ground water resources of East Maui watershed dating back to the late 1800s/early 1900s.

- Plantation and ditch companies operated gauging stations, evaluating water supply in delivery systems (e.g., EMI).
- In 1909, the USGS surface water data collection program began examining water supply potential for agricultural irrigation needs. Emphasis was placed eventually on examining flow characteristics of streams in remote areas.
- Water collected and distributed to residents of Maui County is monitored by Maui County DWS.

Water Resource Monitoring Objectives

- (1) To understand and track changes in the quantity and quality of water resources, including surface, ground, and rainfall.

Surface and Ground Water Quantity

USGS has collected data from approximately 70 surface water gauging stations installed on continuous/perennial and ephemeral streams in East Maui (Appendix 8 - Table A.8.1). Of these 70 stations, only three are currently active:

- Hanawī Stream near Nāhiku (Station ID# 16508000);
- West Wailuaiki Stream near Ke‘anae (Station ID# 16518000);
- Honopou Stream near Huelo (Station ID# 16587000).

An additional 40 surface water gauging stations were originally placed in plantation ditch systems. Although none of these are currently active, EMI maintains and operates four water flow gauging stations along Wailoa Ditch, New Hāmākua Ditch, Lowrie Ditch, and Ha‘ikū Ditch at Honopou. Gauges are checked monthly and reports are generated on a quarterly basis. Water collected by EMI is either delivered to Hawaiian Commercial and Sugar Company’s plantation or upcountry residents and farmers from Ha‘ikū to Kanaio via the DWS distribution system.

In addition to surface water studies, USGS is involved in investigations evaluating ground water contribution to streams, modeling ground water occurrence, and quantifying fog drip in East Maui (personal communication; Steve Gingerich, USGS).

Water Quality

Surface water quality data have been collected at 15 stations in the past, but none of the stations appear to be currently active (Appendix 8 - Table A.8.2). In addition, DWS treats and tests the quality of water it delivers to ensure compliance with all state and federal water quality standards. The DWS Water Quality Laboratory in Kahului is integral to the Department's quality assurance program, performing over 15,000 tests a year to look for more than 300 possible contaminants, many of which are not regulated or detected. Additional information on DWS water resources for East Maui can be found in Appendix 8 - Table A.8.3.

Rainfall

USGS rainfall data help determine (1) recharge and water availability in aquifer systems, (2) when and how much to irrigate crops, and (3) current hydrologic conditions. The density of rain gauges in Hawai'i is one of the highest in the world and almost all of them were initially operated by plantations and ranches. Now, DLNR and the National Weather Service coordinate the network of rain gauges operated by myriad entities. As of March 1993, 123 rain gauges were operated in Maui with three located in the East Maui watershed near long-term surface water quantity trend stations. EMI operates 16 rain gauges within their ditch system (Appendix 8).

Mapping the distribution of rainfall in the watershed (Figure 5) showed that the vast majority of rainfall occurs in unfenced management units. Because these areas are obviously critical to ground water recharge, the data confirm the imperative to evaluate unfenced management units and determine appropriate management actions that support watershed goals.

Stream Macrofauna

In 2003-2004, USGS collected information (unpublished literature) on stream macrofauna habitat availability and utilization at several locations on five streams (Hanawī, Kōpili'ula, Wailuanui, Honomanū, and Waikamoi). This effort was part of a cooperative study with the State of Hawai'i Commission on Water Resource Management on the effects of diversions on streamflow and native macrofauna in northeast Maui. A habitat survey was also done on Palikea Stream in Kīpahulu. EMWP staff assisted USGS in data collection at two sites (personal communication; Alex Michailidis, EMWP). Support was provided to acquaint staff with conducting stream assessments. Such activities may support water resource investigations or public outreach programs with schools and members of the community.

Between 2002-2004, DAR conducted fish counts on seven East Maui streams (Pi'inā'au, Nua'ailua, Wailuanui, Waiokamilo, Kōpili'ula, West Wailuaiki, and Hanawī). Additional information on these investigations is provided in Appendix 8 - Table A.8.4.

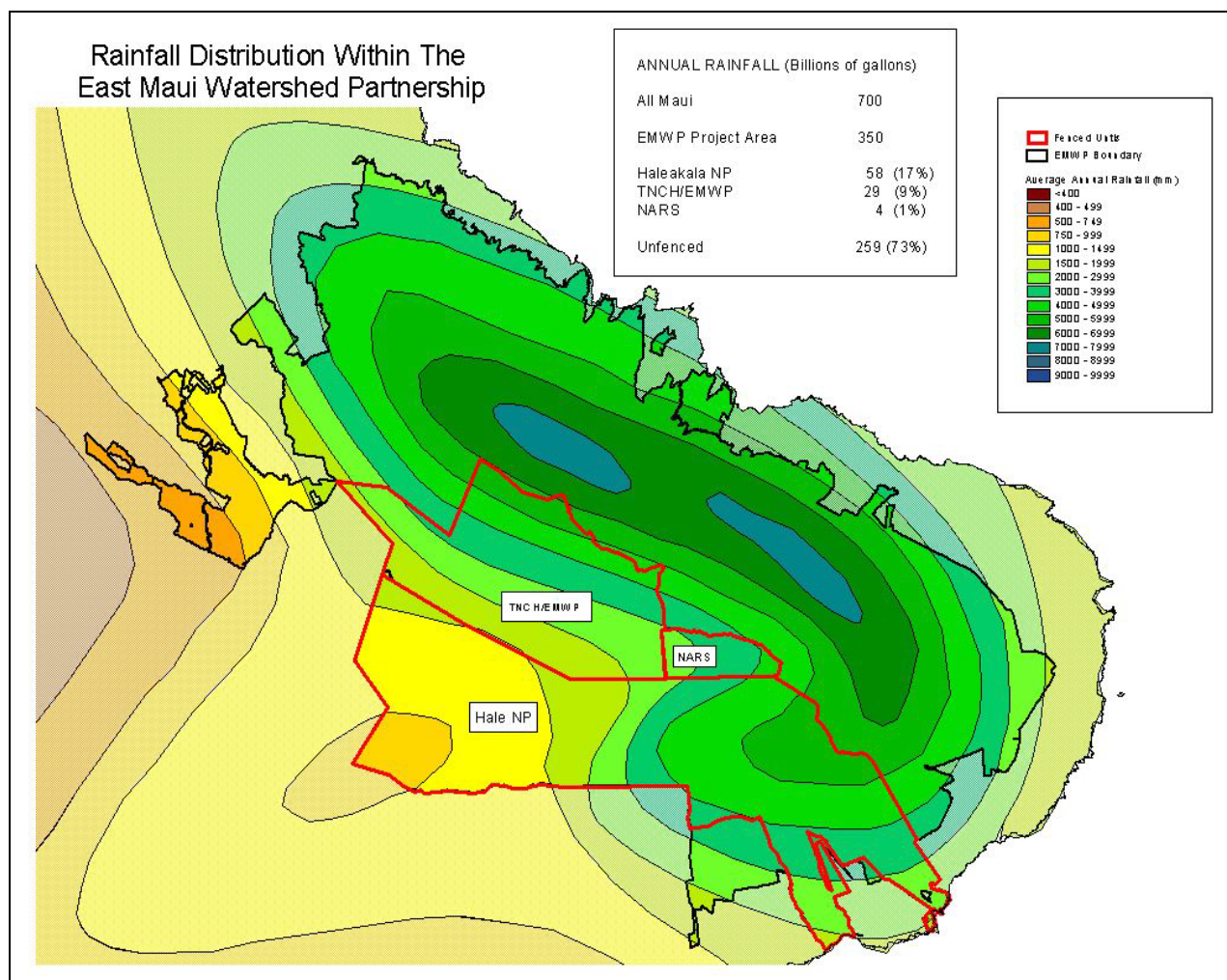


Figure 5. Estimated rainfall distribution in East Maui watershed based on best available data. Rainfall contours interpolated from existing weather stations (note: there is a lack of stations at mid-elevations).

Monitoring Recommendations – Existing Data Collection

- Support partners and public agencies to continue collecting water resources data (i.e., stream flow, ground water, rainfall, water quality) according to their mandates.
- Discuss with USGS the possibility of increasing the number of active gauging stations in the East Maui watershed.
- Assist water resource agencies with data collection as time and resources allow.

Conclusions & Resources Needed

The monitoring review for the East Maui watershed focused entirely on the highest priority threats, namely ungulates and weeds. It is important to keep in mind that there are other significant threats to the natural resources in the watershed including other invasive animals, insects, and non-vascular plants. Although specific monitoring protocols for these other threats were not recommended, it is critical that these threats are monitored informally. Natural resource managers should be aware of all threat issues and share information as it is discovered.

Many of the recommendations in this report supported the continuation of current monitoring activities and methods. However, several new efforts were recommended that require additional resources than currently available.

- (1) Development of a baseline inventory for unfenced management units that is used to propose new active management units and objectives;
- (2) Completion of updated and comprehensive vegetation maps across the watershed; and
- (3) Implementation of a pilot helicopter survey on management units below the fence.

Of these, money is available to initiate a pilot helicopter survey in some portion of the unfenced management units. However, if results are favorable and expansion of this monitoring protocol is recommended, new resources will need to cover additional areas.

In addition, 6 priority research needs were identified (Appendix 9).

- Perform a comprehensive analysis of past ungulate data;
- Determine optimum/minimum transect coverage for Transect AMUs;
- Update pig population estimates, demography, movement, and behavior, particularly in unmanaged areas below the fence;
- Develop a cost-effective method for measuring changes in weed distributions over time across the watershed;
- Develop better estimates of rainfall at mid-elevations; and
- Investigate the link between management actions and water quantity and quality.

The next step is for the various partners of the East Maui watershed to determine if and how these new recommended monitoring efforts and research needs can be accomplished.

Finally, it was clear from the monitoring review that a revision of the EMWP management plan is necessary and timely. The core team suggests the updated management plan address the following issues: (1) defining explicit ungulate activity goals and timeframes for current AMUs, (2) determining explicit weed management goals for all management units, and (3) delineating new AMUs in currently unmanaged areas that capture the best remaining native habitat.

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Appendix 1 – Participants of April 12, 2005 Review Meeting

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7. Jordan Jokiel, East Maui Watershed Partnership
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9. Lloyd Loope, USGS Biological Resources Division
10. Art Medeiros, USGS Biological Resources Division
11. Theresa Menard, The Nature Conservancy of Hawai‘i
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13. David Quisenberry, State Division of Forestry & Wildlife
14. Francis Quitazol, The Nature Conservancy of Hawai‘i
15. Teya Penniman, Maui Invasive Species Committee
16. Bryon Stevens, State Division of Forestry & Wildlife
17. Robert Vincent, The Nature Conservancy of Hawai‘i
18. Erica Von Allmen, USGS Biological Resources Division

Appendix 2 – Details of Past Biological Monitoring

Birds

In 1980, the U.S. Fish and Wildlife Service (USFWS) conducted surveys of forest birds and plant communities on East Maui as part of a larger effort to survey the main Hawaiian Islands. The results of these surveys, known as the Hawai‘i Forest Bird Surveys, are detailed in Scott *et al.* (1986). On Maui, the survey method involved laying out transects at 1.6 to 3.2 km [1 to 2 mile] intervals in native forest bird habitat (Mountainspring 1987). Stations were placed 135 m [440 ft] apart along these transects and sampled from May to August 1980. At each station observers conducted 8-min counts, recording distances to all birds heard or seen. This methodology (the variable circular plot) is a form of distance sampling that estimates abundance of birds based on a detection probability.

Since the 1980 Hawai‘i Forest Bird Survey, additional bird surveys have been conducted on East Maui. Although the results of these surveys are not available yet, it is the goal of the Hawai‘i Forest Bird Interagency Database Project (HFBIDP) to make these data useable and accessible by creating a centralized, standardized database of all forest bird surveys collected since the Hawai‘i Forest Bird Surveys. The HFBIDP will also develop current population size estimates, species-habitat models, and distribution maps for all native and exotic birds in Hawai‘i and examine population trends in species of concern. The results will be presented on a webpage available to cooperators throughout Hawai‘i. HFBIDP data for East Maui comes from the surveys shown in Table A.2.1.

Table A.2.1. East Maui Bird Surveys from 1980 to 2000 (source: HFBIDP 2005).

Survey Area	Organizer	Year	Month	Number of Transects (Stations)
East Maui HFB Survey	USFWS	1980	May-Aug	13 (1001)
Haleakalā	BRD	1993	Mar	11 (208)
	NPS	1996	May	2 (30)
	NPS	1997	Apr	4 (83)
	NPS	1998	May	4 (94)
	NPS	1999	Apr-May	6 (96)
	NPS	2000	Apr-May	6 (112)
Hanawā	BRD	1995	Jan-Dec	4 (40)
	BRD	1996	Jan-Dec	4 (40)
	BRD	1997	Jan-Dec	4 (40)
	BRD	1996	Mar	4 (72)
Kahikinui	DOFAW	1996	Apr	2 (26)
East Maui	DOFAW	1992	Apr-May	14 (425)
	DOFAW	1996	Mar	3 (60)
Waikamoi	TNCH	1994	Mar-Jun	5 (102)
	TNCH	1996	Mar-Jun	5 (110)

Key to Table Abbreviations:

BRD – USGS Biological Resources Division

DOFAW – Division of Forestry and Wildlife

NPS – National Park Service

TNCH – The Nature Conservancy of Hawai‘i

USFWS – U.S. Fish and Wildlife Service

Ungulates

Pig monitoring prior to 1960

Systematic monitoring of pigs can be traced back to the early 1900s when the Hawai'i Territorial Board of Agriculture and Forestry launched a Noxious Animal Eradication Program to control feral pigs throughout the islands. The whereabouts of data from this program, which ran from 1917 to 1958, is unknown. However, Diong (1982) summarized the kill statistics from this program in his dissertation. For Maui, the number of pigs killed annually from 1929 to 1958 ranged from an annual low of 45 pigs in 1933-34 to an annual high of 2,456 pigs in 1949-50. From 1929 to 1958, a total of 7,443 pigs were eradicated on Maui. How the removal of these animals affected the population decline of pigs is unknown, though it clearly did not result in island wide eradication.

Pig monitoring by the State of Hawai'i

In 1959, responsibility for pig control was transferred to the Hawai'i Fish and Game Department (now the Department of Land and Natural Resources or DLNR). To this day, DLNR maintains hunting checking stations and tallies the number of pigs killed as reported by hunters.

In 2002, the DLNR's Division of Forestry & Wildlife installed eight 500-m [1,640 ft] long belt transects (with 5 x 10 m plots; 16 x 33 ft plots) to monitor pig activity in the lower Ko'olau Forest Reserve (i.e., below 1,200 m; 3,900 ft) as part of an agreement that increased public hunting on watershed lands owned/leased by East Maui Irrigation Company (EMI). These eight transects (now currently seven), combined with game harvest reports, are used to track trends in pig activity in the accessible lower elevation areas of the watershed. At some point, the data will be correlated with information on vegetation to gauge whether public hunting is keeping ecosystem disturbance low. Data collected includes presence of various types of activity, age of sign, and percent ground disturbance. Transects are monitored every six months. Three data sets were collected at the time of this writing. Pig activity was quite high (~ 50% frequency).

Monitoring pig removal by Haleakalā National Park

On East Maui, Haleakalā National Park was the first to eradicate pigs from its land, and the first to successfully eradicate pigs in a fenced remote natural area anywhere in Hawai'i. Over a 35-month period (March 1986 to January 1989), the park eradicated pigs from two units (Anderson & Stone 1993). The larger unit (Upper Kīpahulu) was 780 ha [1,900 acres] and contained an estimated 47 pigs at the start of the removal program. Fifty-three pigs were removed from this unit using a snare density of 0.74/ha [0.3/acre]. The smaller unit (Lower Kīpahulu) was 620 ha [1,500 acres] and contained an initial population of 87 pigs. A total of 175 pigs were removed from that unit using a snare density of 2/ha [0.81/acre]. During the removal program, pig activity (fresh and old sign) was monitored along twelve 500-m [1,640 ft] long belt transects. Eight transects were in the larger unit (0.5 transects/km²; 1.3 transects/mi²) and four transects in the smaller unit (0.7 transects/km²; 1.8 transects/mi²). Pig activity transects provided a systematic accounting of pig control progress, as long as the pig population was greater than 1 pig/km² [3 pigs/mi²]. Below this level, scouting off transect was necessary to detect the last few pigs. In Upper Kīpahulu, the most consistent index to predicting pig numbers was the frequency

of fresh digging (arcsine transformed), which started at 8% and dropped to 0% at the end of the program. In the other unit, the digging index was not consistent with pig numbers.

Current pig monitoring efforts outside the Park

Presently, other parcels with no or low pig activity on East Maui include the upper portions of the State's Hanawā Natural Area Reserve (NAR) and TNCH's Waikamoi Preserve. Monitoring in upper Hanawā NAR, which presently contains some 1,600 hectares [3,950 acres] of pig-free area, consists of scouting whereby the presence of any animal sign in the management units initiates immediate animal control. USFWS bird survey transects in Hanawā NAR have not been read for ungulate activity since the mid-1990s.

Monitoring throughout Waikamoi Preserve over the last few years has been conducted annually along portions of five USFWS bird survey transects (transects 2-6; see Figure A.2.1), with detection of any fresh activity leading to immediate management in the upper units (Units 4 and 5) where pig activity is lowest. TNCH has been estimating animal sign (fresh only) to the nearest percentage in 5 x 50 m [16 x 164 ft] plots. Thirty 500-m [1,640 ft] long transects were located in Waikamoi Preserve and adjacent EMI lands in the late 1980s but these have not been monitored since 1998.

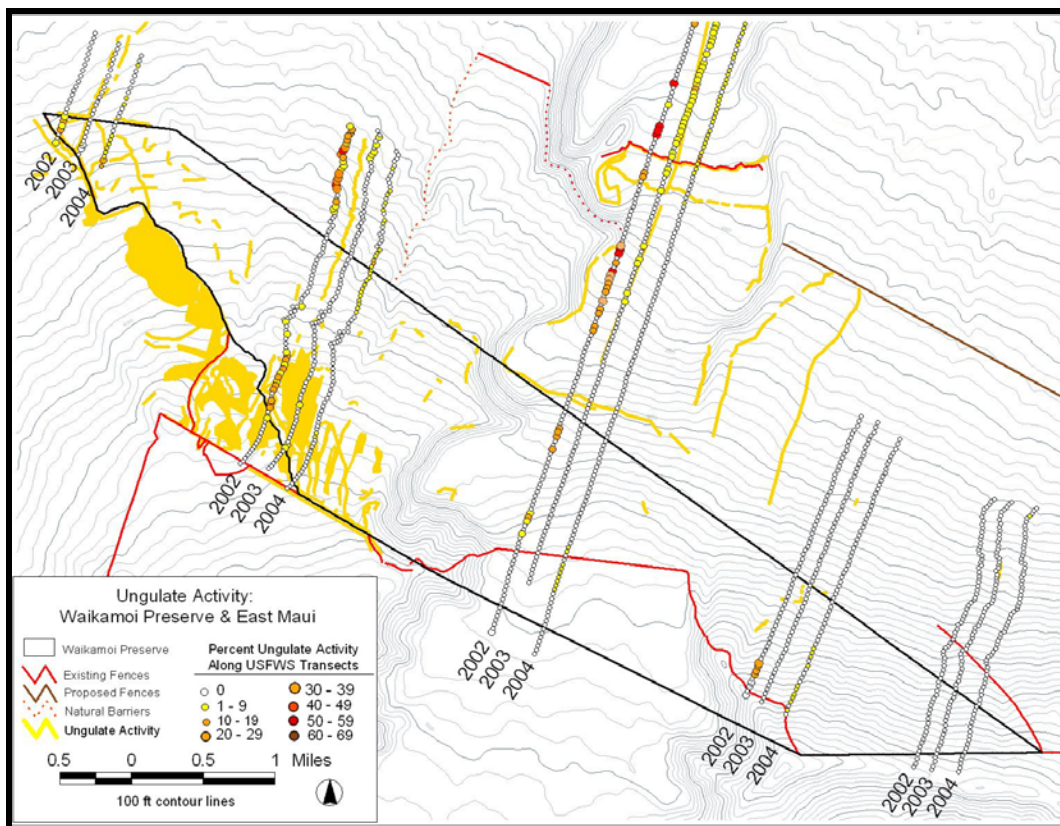


Figure A.2.1. Percent ungulate activity for 2002-2004 along USFWS bird survey transects 2-6.

The EMWP started additional monitoring on lands owned by the State and EMI. In 2003/2004, the EMWP placed nine transects of varying lengths within its Wailuanui management unit (406 ha; 1,000 acres). Ungulate sign is estimated to the nearest percent in 5 x 10 m [16 x 33 ft] plots. In the Wailuaiki unit, transects will be placed in natural openings in the forest as well as in

drainages and on pig trails. Impenetrable areas are extremely difficult to monitor and thus, transects are placed only within the corridor created by recently constructed fence lines.

Weeds and Vegetation

Jacobi vegetation monitoring in 1980s

One important early botanical survey followed the original USFWS forest bird surveys along transects 1-13 in 1980. Vegetation on those surveys was characterized at bird stations and occasionally in between stations if something significant appeared. Vegetation was characterized by groups (e.g., exotic shrubs, native grasses) and group cover values were estimated using the Braun-Blanquet scale. Canopy dominants were noted, and weeds were noted when they first appeared as observers moved down the mountain.

Waikamoi vegetation and weed monitoring in 1993 & 1994

Vegetation and weed monitoring at TNCH's Waikamoi Preserve was done in 1993 and 1994 using the Dunn Protocol (Dunn 1992). Guy Hughes, then biologist for TNCH-Maui (presently at Kalaupapa National Historical Park), performed the data analysis and wrote two internal reports, one on vegetation and one on pest plants (Hughes 1995a, 1995b). Vegetation data were collected in 58, 250 m² [2,700 ft²] circular plots spaced 250 meters [820 ft] apart on USFWS transects 3-6. Weed data were collected in contiguous 5 x 50 m [16 x 164 ft] rectangular plots along the same transects. Vegetation information included: complete plant species enumeration in each plot; counts of individual species in five height categories; cover estimates of individual species in five height categories using both point-intercept and visual estimates using the Braun-Blanquet cover scale; tree vigor assessment; and visual estimates of epiphytic cover in five height categories. Weed cover (in the 5 x 50 m plots; 16 x 164 ft) was also estimated in five height categories.

East Maui watershed pilot monitoring project 1996

From November 1995 to February 1996, TNCH conducted a pilot monitoring project for the East Maui watershed (TNCH 1996). Vegetation, weed, and ungulate activity monitoring was done using a "modified" Dunn protocol. Coleen Cory (former ecologist with TNCH) performed the data analysis and report writing. Vegetation data were collected in 250 m² [2,700 ft²] plots at the same locations on USFWS transects as in 1993/94. However, unlike the 1993/94 monitoring, only transects 4 and 6 were sampled, and every other plot was sampled such that plots were 500 m apart [1,640 ft] rather than 250 m apart [820 ft]. Data were collected inside and below Waikamoi Preserve. Weed and ungulate activity data were collected in the same 5 x 50 m [16 x 164 ft] contiguous rectangular plots along transects 4 and 6 as done in 1993/94. Vegetation information included: complete plant species enumeration in each plot; counts of individual species; cover estimates of individual species in five height categories using point-intercept, a periscope, and visual estimates to the nearest 10%; and substrate characterization. Weed cover in the 5 x 50 m [16 x 164 ft] plots was estimated in five height categories.

Additional monitoring

Periodic monitoring for weeds occurred along USFWS transects 2-6 in Waikamoi Preserve. Some weed monitoring has occurred sporadically at Hanawā NAR. Haleakalā National Park has undertaken numerous projects (past and current) related to assessing vegetation and weed status. A sampling of their work is highlighted online at: <http://www.hear.org/usgs-brd-pierc-hfs/>.

Appendix 3 – Details of Active Management Units

Table A.3.1. Scouting AMUs in East Maui.

AMU	Approximate Size Hectares [Acres]
Haleakalā National Park	12,000 [29,650]
Hanawī Natural Area Reserve – 3 Units	650 [1,600]
Waikamoi Preserve – 4 Units	1,600 [4,000]
Total	14,250 [35,250]

Table A.3.2. Transect AMUs in East Maui.

AMU	Area in Hectares [Acres]	# Transects	# Stations	Sum of Transect Lengths in Meters [Feet]	Meters of Transect per Hectare of AMU [Feet per acre]	Comments
Honomanū makai	396 [979]	4	258	2,580 [8,465]	6.5 [8.6]	Lower portions of unit are somewhat open and accessible. Managers feel the four recently installed transects provide adequate coverage of the lower unit. Time needs to be spent scouting the upper, more forested areas. Soil is almost always saturated and the weather is generally bad. Drainages are steep sided and terrain is dangerous.
Wailuanui	406 [1,003]	8	595	5,950 [19,520]	15 [20]	Much of the lower unit has an ‘ōhi‘a/ ‘ōlapa overstory and a relatively open understory. The upper unit (above 1,675 m; 5,500 ft) is dense shrubland. Uluhe stands are dense but not dominant and seem to be concentrated on the eastern side. Transects have been nested within management trails that cover the lower two-thirds. Fresh pig sign is always present. Drainages are steep and terrain is dangerous.

Table A.3.2. (continued) Transect AMUs in East Maui.

AMU	Area in Hectares [Acres]	# Transects	# Stations	Sum of Transect Lengths in Meters [Feet]	Meters of Transect per Hectare of AMU [Feet per acre]	Comments
Wailuaiki	387 [956]	1	145	1,450 [4,757]	4 [5.3]	Unit is almost entirely dominated by impenetrable stands of uluhe. Only one transect has been installed (along entire fence line). Some time was spent looking on the ground for other disturbance corridors in which to place additional transects. None were found. An aerial scouting trip revealed three natural openings above the fence line. Transects may be placed in these areas if they can be accessed. Drainages are steep and terrain is dangerous.
Kōpili‘ula	847 [2,093]	0	0	0	0	Fence is being built in this unit. Area appears as dense and impenetrable as Wailuaiki. After completion of the fence, a transect will be placed along the entire contour fence. Scouting needs to be done before additional transects can be installed. Drainages are steep and terrain is dangerous.
Ko‘olau Gap	611 [1,510]	4 proposed	250	2,000 [6,562]	3 [4]	Encompasses native dominated wet forest in upper elevations transitioning to alien dominated wet ecosystems at lower elevations. Ranges from dense, uluhe-dominated understory to relatively open. Pig activity ranges from zero to moderate, especially at lower elevations.
Waikamoi Unit 1A	245 [605]	3 proposed	150	1,500 [4,921]	6 [8]	Primarily comprised of Koa/‘Ōhi‘a Montane Wet and Mesic Forest. Higher levels of pig activity due to hunting as main removal method. Relatively open understory allows for reading of transects annually.
Waikamoi Unit 2	350 [865]	3 proposed	150	1,500 [4,921]	4 [5.3]	Dominated by dense conifer stands, surrounded by alpine shrublands and ‘Ōhi‘a Montane Wet Forest at lower elevations. Higher levels of pig activity in this unit. Relatively open or accessible understory allows for transects.

Appendix 4 – Details on Age of Ungulate Sign

Type of Sign	Hunter Fresh	Old	Too Old
Digging	Fluffy soil, mud clumps with distinct edge features, edges still moist, soil clumps on rootlets, soil still falling into hole, dug up plants not wilted	Soil clumps weathered, or dry at edges, seedlings emerging, soil washed off of rootlets, loose rocks, plants wilted	Cannot distinguish from water caused erosion
Wallows	Evenly mixed, mud has chocolate pudding texture, hair imprint distinct, mud spatters around hole	Soil precipitating out, layer of water on top	Vegetation established in hole, cannot tell from natural feature
Tracks/trails	Edges of prints sharp, dirt still falling into hole	Track edge eroded, leaf litter in print	Cannot distinguish from water caused erosion
Scats	Strong smell, still slimy, flies, distinct outer edges	Dried, eroded, puddled on ground, seedlings, fungus/lichen/algal growth present	In dry environment, white and powdery
Plant feeding	Plant material still salad bar fresh, oozing sap, not wilted	Plants browning or wilted, hāpu‘u core darkening	Hāpu‘u core hollowed out by rats, moss cover, injured bark healing over
Rubs/scrapes	Wet soil on tree trunk, hair imprint, still oozing sap	Dry soil on tree trunk	Soil washed off tree trunk, injured bark healing over
Other	Strong barnyard stench, sound, sight	Weak smell of pigs	

Appendix 5 – Details on Priority Weed Species

Species	Elevation in Meters [Feet]	Problem Management Units	Incipient (I) or Established (E)*	Control Agencies
<i>Acacia</i> species <i>A. melanoxylon</i> , <i>A. mearnsii</i>	Varies by species	Waikamoi, Makawao FR, HALE shrublands	E	TNCH
<i>Acacia</i> species <i>A. auriculiformis</i> , <i>A. mangium</i> , <i>A. podalyriifolia</i> , <i>A. retinodes</i>	Varies by species	Makawao FR	I	MISC
African tulip <i>Spathodea campanulata</i>	0 – 975 [0 – 3,200]	Kīpahulu	E	HALE
Andean pampas grass <i>Cortaderia jubata</i> , <i>C. selloana</i>	150 – 2,800 [490 – 9,200]	Honomanū, HALE shrublands, Waikamoi	E	TNCH, MISC, EMWP, HALE
Australian treefern <i>Cyathea cooperi</i>	550 – 1,160 [1,800 – 3,800]	Kīpahulu	E	HALE
Broomsedge <i>Andropogon virginicus</i>	0 – 2,130 [0 – 7,000]	Waikamoi, Kīpahulu, Manawainui, Kaupō	E	HALE, TNCH
Christmas berry <i>Schinus terebinthifolius</i>	0 – 1,585 [0 – 5,200]	Kaupō, Kīpahulu	E	HALE
Common guava <i>Psidium guajava</i>	0 – 1,250 [0 – 4,100]	Entire EMWP	E	TNCH, HALE
<i>Ficus</i> species <i>F. microcarpa</i> , <i>F. rubiginosa</i> , <i>F. microcarpa</i>	0 – 610 [0 – 2,000]	Entire EMWP	E	HALE
Firetree <i>Morella faya</i>	975 – 2,130 [3,200 – 7,000]	Waikamoi, Kilohana	E	TNCH, MISC
Glenwood grass <i>Sacciolepis indica</i>	610 – 5,440 [2,000 – 17,850]	Honomanū, Ko‘olau Gap, HALE bogs,	E	EMWP
Gorse <i>Ulex europaeus</i>	610 – 7,200 [2,000 – 23,600]	Waikamoi, HALE shrublands	E	HALE, TNCH
Hilo grass <i>Paspalum conjugatum</i>	0 – 1,360 [0 – 4,500]	Entire EMWP	E	HALE
Inkberry <i>Ardesia elliptica</i>	0 – 610 [0 – 2,000]	Kīpahulu	E	HALE
<i>Juncus</i> species <i>J. planifolius</i> , <i>J. effusus</i> , <i>J. polyanthemus</i>	670 – 2,375 [2,200 – 7,800]	Waikamoi, Honomanū, Ko‘olau Gap, HALE bogs	I	HALE, EMWP

Species	Elevation in Meters [Feet]	Problem Management Units	Incipient (I) or Established (E)*	Control Agencies
Kāhili ginger <i>Hedychium gardnerianum</i>	610 – 1,770 [2,000 – 5,800]	Entire EMWP	E	HALE, EMWP, TNCH
Kikuyu grass <i>Pennisetum clandestinum</i>	610 – 2,440 [2,000 – 8,000]	Kaupō	E	HALE
Koster’s curse <i>Clidemia hirta</i>	0 – 1,280 [0 – 4,200]	Entire EMWP	E	HALE, EMWP
Maui pāmākani <i>Ageratina adenophora</i>	0 – 2,440 [0 – 8,000]	Entire EMWP	E	TNCH
<i>Miconia calvescens</i>	0 – 610 [0 – 2,000]	Entire EMWP	E	All agencies
Molasses grass <i>Melinis minutiflora</i>	0 – 1,525 [0 – 5,000]	Kaupō	E	HALE
Mule’s foot fern <i>Angiopteris evitica</i>	150 – 1,005 [490 – 3,300]	Kīpahulu	I	HALE
Palmgrass <i>Setaria palmifolia</i>	305 – 1,525 [1,000 – 5,000]	Waikamoi, Ko‘olau Gap, Honomanū	E	EMWP, TNCH, HALE
<i>Pinus</i> species <i>P. patula</i> , <i>P. radiata</i>	915 – 2,745 [3,000 – 9,000]	Waikamoi Unit 2, HALE shrublands	E	HALE, TNCH
Rose apple <i>Syzygium jambos</i>	0 – 670 [0 – 2,200]	Entire EMWP	E	HALE
<i>Rubus</i> species <i>R. argutus</i> , <i>R. ellipticus</i> , <i>R. glaucus</i> , <i>R. rosifolius</i> , <i>R. niveus</i>	Varies by species	Entire EMWP	E	HALE, TNCH, MISC
Silk oak <i>Grevillia robusta</i>	1,280 [4,200]	Kaupō	I	HALE
Strawberry guava <i>Psidium cattelianum</i>	90 – 1,645 [295 – 5,400]	Entire EMWP	E	All agencies
<i>Tibouchina herbacea</i>	0 – 1,645 [0 – 5,400]	Entire EMWP	E	HALE

Key to Table Abbreviations:

EMWP – East Maui Watershed Partnership

FR – Forest Reserve

HALE – Haleakalā National Park

MISC – Maui Invasive Species Committee

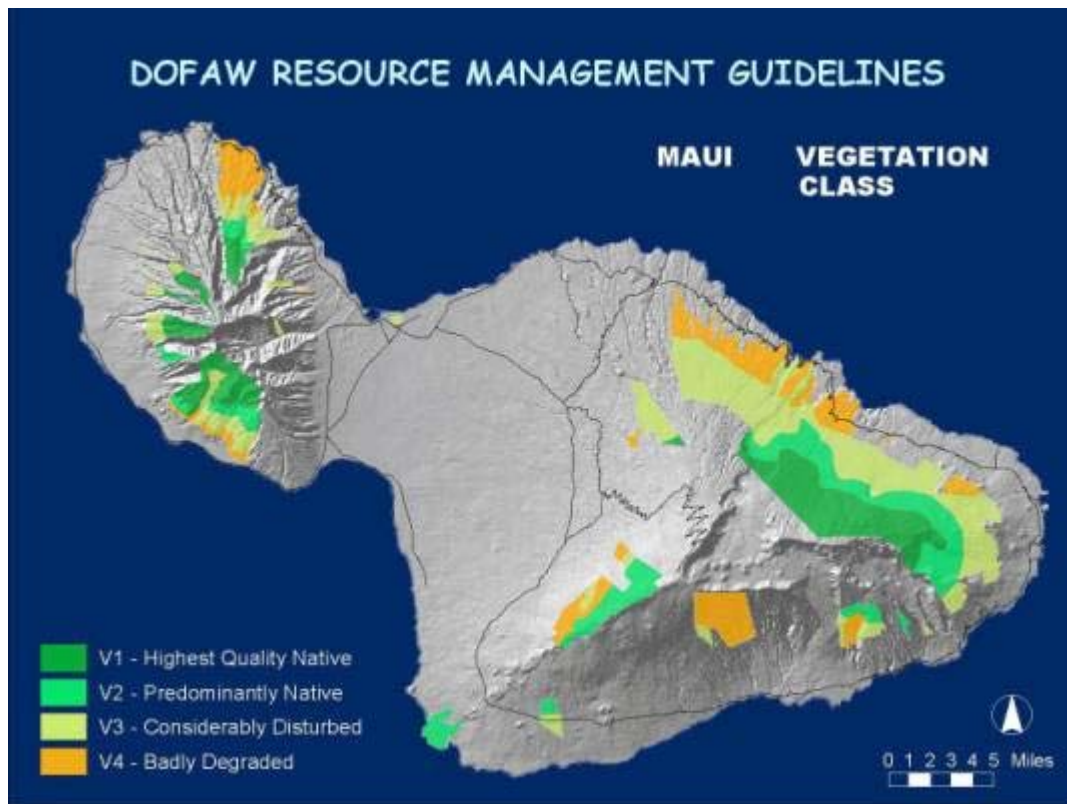
TNCH – The Nature Conservancy of Hawai‘i

**Established* = Species established with persistent seed bank

**Incipient* = Species not yet established with persistent seed bank

Appendix 6 – Vegetation Quality Categories

DOFAW Vegetation Quality Designations



V-1: Highest Quality Native Ecosystems

V-1 units consist of the highest quality native ecosystems and communities. They have minimal disturbance and low levels (less than 10%) of non-native plants in any vegetative layer. Examples are portions of the Alaka'i Wilderness Preserve (Kaua'i), 'Eke Crater (Maui), Wright Road section of Pu'u Maka'ala NAR (Hawai'i).

V-2: Predominantly Native Areas

V-2 units consist of areas where native plants predominate in communities that are relatively intact and are minimally disturbed. They have a significant component of non-native plants (more than 10%). Examples are the most native portions of some NARs and Forest Reserves.

V-3: Considerably Disturbed Areas

V-3 units have a considerable amount of disturbance. The vegetation does not reflect a naturally evolved species composition, but rather a mixture of small remnant patches dominated by native plants, patches of largely invasive weedy aliens, and areas of mixed native and non-native plants. Examples are portions of Pu'u Ka Pele Forest Reserve (Kaua'i), Pu'u Wa'awa'a public hunting area (Hawai'i).

V-4: Badly Degraded Areas

V-4 units are severely degraded or highly altered. They may have been cleared for other uses, or are currently eroded, forest plantations, or are dominated by non-native species. Examples are portions of the Kekaha Game Management Area (Kaua'i) and Pu'u Anahulu Game Management Area (Hawai'i).

Proposed Vegetation Quality Categories for East Maui Watershed

Letter grades are suggested to make the rankings more intuitive than the DOFAW “V” scale. The scale is similar to DOFAW’s designations and is a continuum. Vegetation patches of different rankings can be adjacent (i.e., C may be adjacent to F without D in-between).

A: Pristine native vegetation

Greater than 90% native cover. Non-native plants are generally short-lived, herbaceous species, mostly restricted to drainages or disturbed areas and limited to 10% or less cover. Native diversity is high; understory shows little or no evidence of disturbance.

B: Predominantly native

Between 60-90% native cover. Some weed component; 10% to 33% cover, generally restricted to understory, but could also be young canopy species emerging from native understory. Weed species typically longer lived types than in rank A (woody plants, grasses, etc.). Native diversity is still high, although some sensitive species may be rare. Bare soil exposure and altered understory composition may reflect a fair amount of disturbance.

C/D: Degraded native

Native canopy >50%, but understory largely weeds, and native diversity reduced. Disturbance may have been severe enough to create artificial openings in the native canopy, or canopy and understory more weeds than native. Diversity greatly reduced. Disturbance has removed most of the original native canopy; some interlocking crowns remaining.

E: Exception

Canopy of non-native species with predominantly native understory component. Rarely seen; examples could be certain higher elevation plantation timber stands, or sometimes kukui groves. Highly disturbed or weedy sites would be classed as D.

F: Non-native

Native elements reduced to rare relicts (<50%). Typical of old agricultural sites and other areas subject to intensive clearing. Disturbance has reduced native canopy to very scattered, isolated trees.

Appendix 7 – Sample Data Fields for Helicopter Surveys

- Date
- Waypoint ID
- Latitude
- Longitude
- Observer
- Weather

- Plant community type (pick from list)
- Vegetation quality assessment (A-F)

- Presence of priority weed Species 1 – light, moderate, heavy
- Presence of priority weed Species 2 – light, moderate, heavy
- Etc.
- Ungulate activity (all sign) – light, moderate, heavy

Appendix 8 – Details of Water Resource Monitoring

U.S. Geological Survey (USGS)

Surface water data consist of continuous record gauges, crest stage gauges, low-flow partial record gauges, and miscellaneous measurement sites (commonly only a one-time data collection event). Continuous record gauges collect data (e.g., surface water elevation) on a continuous basis and can be used to compute stream flow at any particular time. Crest-stage gauges provide only the peak stream elevation that occurred between servicing visits to the gauge, and such data can be used to compute discharges for selected flood peaks. Low flow partial record gauges are non-recording gauges where measurements of stream flow and elevation are made during times of low flow.

Table A.8.1. East Maui Watershed Surface Water Gauging Stations (through 1994).

Station ID#	Station Name	Station Type	Period of Record	Stream Classification
16500800	Kukui‘ula Gulch near Kīpahulu	SW-CSG	1963-1968	Ephemeral
16501000	Palikea Stream below dam diversion near Kīpahulu	SW	1927-1983	Continuous
16501200	‘Ohe‘o Gulch at dam near Kīpahulu	SW	1988-Present	Continuous
16502000	Hāhālawe Gulch near Kīpahulu	SW	1927-1969	Continuous
16502400	Pūku‘ilua Gulch near Hāna	SW-CSG	1963-Present	Ephemeral
16502800	Mo‘omo‘onui Gulch near Hāna	SW-CSG	1963-Present	Continuous
16502900	Kawaipapa Gulch near Hāna	SW-CSG	1963-Present	Continuous
16506500	West Makapipi Spring near Nāhiku	Spring	1932-1945	Continuous
16507000	Makapipi Stream near Nāhiku	SW	1932-1945	Continuous
16508000	Hanawī Stream near Nāhiku	SW	1921-Present	Continuous
16509000	Hanawī Stream below government road near Nāhiku	SW	1932-1947 1992-Present	Continuous
16510000	Kapa‘ula Gulch near Nāhiku	SW	1921-1963	Continuous
16511000	Kapau Gulch below government road near Nāhiku	SW	1932-1947	Continuous
16513000	Wai‘a‘aka Stream near Nāhiku	SW	1932-1947	Continuous
16514000	Pa‘akea Gulch near Nāhiku	SW	1932-1947	Continuous
16515000	Waiohue Gulch near Nāhiku	SW	1921-1963	Continuous
16516000	Kōpili‘ula Stream near Ke‘anae	SW	1914-1958	Continuous
16517000	East Wailuaiki Stream near Ke‘anae	SW	1913-1958	Continuous
16518000	West Wailuaiki Stream near Ke‘anae	SW	1921-Present	Continuous
16519000	West Wailuanui Stream near Ke‘anae	SW	1913-1958	Continuous
16520000	East Wailuanui Stream near Ke‘anae	SW	1914-1958	Continuous
16521000	Wailuanui Stream near Ke‘anae	SW	1932-1947	Continuous
16524000	Honomanū Stream at Ha‘ikū-uka boundary near Ka‘ili‘ili	SW	1919-1968	Continuous
16525000	Seventh Branch Honomanū Stream at Ha‘ikū-uka near Ka‘ili‘ili	SW	1932-1933	Continuous
16526000	Fourth Branch Honomanū Stream at Ha‘ikū-uka near Ka‘ili‘ili	SW	1932-1933	Continuous
16531100	Haipua‘ena Stream at Kula pipeline intake near Olinda	SW	1946-1968	Continuous
16532000	Haipua‘ena Stream at Ha‘ikū-uka boundary near Ka‘ili‘ili	SW SW-LF	1919-1934 1962-1968	Continuous

Station ID#	Station Name	Station Type	Period of Record	Stream Classification
16533000	Third Branch Haipua'ena Stream at Ha'ikū-uka near Ka'ili'ili	SW	1932-1933	Continuous
16534000	First Branch Haipua'ena Stream at Ha'ikū-uka near Ka'ili'ili	SW	1932-1933	Continuous
16536000	Haipua'ena Stream above Spreckels Ditch near Huelo	SW	1913-1967	Continuous
16537000	Haipua'ena Stream near Huelo	SW	1910-1913	Continuous
16542000	East Branch Puohokamoa Stream at Ha'ikū-uka boundary near Ka'ili'ili	SW SW-LF	1919-1933 1963-1968	Continuous
16543000	Middle Branch Puohokamoa Stream at Ha'ikū-uka boundary near Ka'ili'ili	SW	1919-1934 1962-1969	Continuous
16544000	West Branch Puohokamoa Stream at Ha'ikū-uka boundary near Ka'ili'ili	SW	1919-1934	Continuous
16545000	Puohokamoa Stream above Spreckels Ditch near Huelo	SW	1913-1971	Continuous
16546000	Puohokamoa Stream near Huelo	SW	1910-1913	Continuous
16552600	Waikamoi Stream near Pu'ulū'au near Olinda above reservoir at Kula pipeline intake near Olinda	SW	1949-1966	Ephemeral
16552800	Waikamoi Stream above reservoir at Kula pipeline intake near Olinda	SW	1953-1968	Continuous
16553000	Waikamoi Stream below reservoir at Kula pipeline intake near Olinda	SW	1945-1949	Continuous
16554000	Waikamoi Stream at Ha'ikū-uka boundary near Ka'ili'ili	SW	1918-1933	Continuous
16554500	East Branch Waikamoi Stream at Ha'ikū-uka boundary near Ka'ili'ili	SW	1918-1933	Continuous
16555000	Waikamoi Stream above Wailoa Ditch near Huelo	SW	1922-1957	Continuous
16556000	Waikamoi Stream near Huelo	SW	1910-1922	Continuous
16557000	Alo Stream near Huelo	SW	1910-1957	Continuous
16565000	Ka'aiea Gulch near Huelo	SW	1921-1962	Continuous
16566000	'O'opuola Stream near Huelo	SW	1930-1957	Continuous
16567000	'O'opuola Stream above Spreckels Ditch crossing near Huelo	SW	1910-1915	Continuous
16569000	Second Branch Nā'ili'ilihā'ele Stream at Ha'ikū-uka	SW	1932-1933	Continuous
16569100	Nā'ili'ilihā'ele Stream near Ka'ili'ili	SW-LF	1963-1968	Ephemeral
16569700	West Branch Nā'ili'ilihā'ele Stream near Ka'ili'ili	SW-LF	1966-1968	Ephemeral
16570000	Nā'ili'ilihā'ele Stream near Huelo	SW	1910-1975	Continuous
16571000	Nā'ili'ilihā'ele Stream below new Hāmākua Ditch near Huelo	SW	1912	Continuous
16574000	Kailua Stream at Ha'ikū-uka boundary near Ka'ili'ili	SW	1918-1934	Continuous
16574500	Kailua Stream near Ka'ili'ili	SW	1963-1971	Continuous
16575000	Tenth Branch Kailua Stream at Ha'ikū-uka near Ka'ili'ili	SW	1932-1933	Ephemeral
16576000	Ninth Branch Kailua Stream at Ha'ikū-uka near Ka'ili'ili	SW	1932-1933	Ephemeral
16576200	East Branch Kailua Stream near Ka'ili'ili	SW-LF	1963-1968	Continuous
16577000	Kailua Stream near Huelo	SW	1910-1958	Continuous

Station ID#	Station Name	Station Type	Period of Record	Stream Classification
16580000	Oanui Stream near Huelo	SW	1910-1916	Continuous
16591000	Honopou Stream at Lowrie Ditch siphon near Huelo	SW	1932-1947	Continuous
16593000	Honopou Stream above Ha'ikū Ditch near Huelo	SW	1932-1947	Continuous
16595000	Honopou Stream below Ha'ikū Ditch near Huelo	SW	1932-1947	Continuous
16596200	Halahaku Gulch near Ka'ili'ili	SW	1965-1971	Continuous
16598000	Halahaku Gulch near Huelo	SW	1910-1912	Continuous
16599000	East Branch 'Ōpana Gulch at Ha'ikū-uka boundary near Ka'ili'ili	SW	1932-1933	Continuous
16602400	'Awalau Gulch near Ka'ili'ili	SW	1965-1971	Continuous
16603300	Unnamed Gulch at Māliko Bay	SW-CSG	1963-Present	Ephemeral
16603700	Kalialinui Gulch tributary near Pukulani	SW-CSG	1963-Present	Ephemeral
16603800	Kaluapulani Gulch tributary near Pukulani	SW-CSG	1963-Present	Ephemeral

Key to Table Abbreviations:

SW – Continuous record surface water station

SW-CSG – Crest stage gauge

SW-LF – Low flow partial record station

Spring – Station that measures discharge from spring

Continuous flow or perennial streams include those considered continuous or interrupted in the Hawai'i stream assessment (Hawai'i DLNR 1990). Continuous flow streams flow to the sea year-round. Interrupted flow streams flow year-round in the upper parts and intermittently at lower elevations. Ephemeral flow or intermittent streams are those that do not meet the above criteria and flow only in response to precipitation events.

Table A.8.2. East Maui Watershed Gauging Stations with Surface Water Quality Data.

Station ID#	Station Name	Period of Record
16508000	Hanawī Stream near Nāhiku	1972-1989 (N) 1972-1977 (P)
16512000	Ko‘olau Ditch at Nāhiku weir near Nāhiku	1976-1985 (N) 1976-1977 (P)
16518000	West Wailuaiki Stream near Ke‘anae	1972-1989 (N) 1972-1977 (P)
16523000	Ko‘olau Ditch near Ke‘anae	1976-1985 (N) 1976-1977 (P)
16531000	Kula diversion from Haipua‘ena Stream near Olinda	1976-1985 (N) 1976-1977 (P)
16538000	Spreckels Ditch at Haipua‘ena weir near Huelo	1976-1985 (N) 1976-1977 (P)
16541000	Ko‘olau Ditch at Haipua‘ena near Huelo	1976-1987 (N) 1976-1977 (P)
16541500	Manuel Luis Ditch at Puohokamoa Gulch near Huelo	1976-1985 (N) 1976-1977 (P)
16570000	Nā‘ili‘ilihā‘ele Stream near Huelo	1972-1975 (N) 1972-1975 (P)
16587000	Honopou Stream near Huelo	1976-1989 (N) 1976-1977 (P)
16588000	Wailoa Ditch at Honopou near Huelo	1976-1985 (N) 1976-1977 (P)
16589000	New Hāmākua Ditch at Honopou near Huelo	1976-1985 (N) 1976-1977 (P)
16592000	Lowrie Ditch at Honopou Gulch near Huelo	1976-1985 (N) 1976-1977 (P)
16594000	Ha‘ikū Ditch at Honopou Gulch near Kailua	1976-1985 (N) 1976-1977 (P)
16599500	‘Ōpana Tunnel near Ka‘ili‘ili	1972-1989 (N) 1972-1976 (P)

(N) = Physical parameters

(P) = Common ions, metals, and general organic parameters

East Maui Irrigation Company (EMI)

EMI rain gauge stations, recording data weekly, monthly, or quarterly:

- Waikamoi Upper Flume
- Waikamoi Lower Flume
- Puohokamoa Upper Flume
- Puohokamoa #2
- Olinda Reservoir #1
- Olinda Reservoir #2
- Honomanū
- Ke‘anae
- Ho‘olawa
- Waikamoi
- Lupi
- Ka‘ili‘ili
- Wailuaiki #5
- Wailuaiki #6
- Wailuaiki #8
- Pu‘u Pākī

County of Maui Department of Water Supply (DWS)

Table A.8.3. East Maui Water Systems and Sources.

Water System	Service Area	East Maui Water Source
Makawao	Ha‘ikū-Pa‘uwela Hāli‘imaile Kokomo-Kaupakalua Kuiaha Makawao Pukalani	<ul style="list-style-type: none"> • Groundwater from the Ha‘ikū and Kaupakalua wells • Surface water collected in EMI’s Wailoa Ditch and treated at the Kamole Weir Water Treatment Facility (WTF)
Lower Kula	Olinda Kula Kai Ōma‘opio Pūlehu	<ul style="list-style-type: none"> • Surface water collected/treated in Pi‘iholo Reservoir/Pi‘iholo WTF
Upper Kula	Upper Kula Waiakoa Kēōkea ‘Ulupalakua Kanaio	<ul style="list-style-type: none"> • Surface water collected/treated in Waikamoi and Kahakapao Reservoirs/Olinda WTF
Ke‘anae	Ke‘anae	<ul style="list-style-type: none"> • Groundwater from the Ke‘anae well
Nāhiku	Nāhiku	<ul style="list-style-type: none"> • Water from the Nāhiku tunnel
Hāna	Wākiu Hāna Hāmoa Kaupō	<ul style="list-style-type: none"> • Groundwater from the Wākiu and Hāmoa wells

DLNR, Division of Aquatic Resources (DAR)

Table A.8.4. Fish Counts in East Maui Streams.

Date	Stream	Elevation Range of Study in Meters [Feet]	Number of Observations*
4/30/02	Pi'inā'au Stream	4.3 – 89 [14 – 291]	102
5/1/02	Nua'ailua Stream	0.6 – 131 [2 – 431]	94
5/1/02	Wailuanui Stream	0.9 – 61 [3 – 200]	76
5/2/02	Waiokamilo Stream	26.5 – 159 [87 – 521]	92
1/21/03	Kōpili'ula Stream	477 – 574 [1,565 – 1,884]	38
1/22/03	West Wailuaiki Stream	433 – 493.5 [1,455 – 1,619]	29
2/10/04	Hanawī Stream	0.6 – 49 [2 – 160]	54

*Information on species observed is directly available from DAR.

Appendix 9 – Research Needs

Ungulates

- ***Perform a comprehensive analysis of existing ungulate activity data.*** Compare historical (prior to management) versus current activity levels with ongoing management. Compare activity levels in management units above and below fences. Determine trends over time period data were collected.
- ***Determine the optimum/minimum spatial coverage of monitoring transects.*** Determine the optimum/minimum spatial coverage of monitoring transects in Transect AMUs based on size of AMU, topography, vegetation, and other site conditions.
- ***Document pig population estimates, demography, movement, and behavior.*** Update life history information of pigs on East Maui based on radio collaring individuals, mark and recapture studies, etc. More empirical data are needed on actual population estimates throughout the watershed, home ranges, movement patterns, breeding areas, and cycles.

Weeds

- ***Develop a method to measure changes in weed distributions over time.*** Develop and implement a weed sampling protocol that measures the extent (and density?) of major habitat-modifying species across a large-scale (> 50,000 acres; 20,200 ha). The protocol should be a cost-effective, rapid assessment that is repeatable over time.

Water Resources

- ***Improve rainfall estimates at mid-elevations.*** Estimate rainfall across mid-elevation sites in East Maui (2,000 – 4,000 ft; 610 – 1220 m) based on gauge readings (i.e., where none currently exist).
- ***Investigate the relationship between current management actions and water quality and quantity.*** Determine whether management actions (such as removal of habitat modifying weeds and ungulates) result in changes to stream water quality or quantity (such as aquifer recharge).